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EXPERIMENT POINTING SUBSYSTEMS (EPS) REQUIREMENTS FOR SPACELAB MISSIONS

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George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

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16. ABSTRACT

The goal of the Experiment Pointing Subsystems (EPS) is to accommodate a broad spectrum of instrument types by providing a number of stability and control functions that greatly exceed the capability of the Shuttle. These functions include target acquisition, target tracking through wide gimbal ranges, stabilization, simultaneous pointing to one or more targets, instrument rastering, and on-orbit calibration. The experiments will vary widely in size, weight, geometry, and instrument types, and many have not been completely defined. This great diversity of requirements reflects the long term plans of the user community and establishes challenging performance requirements for the EPS.

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EXPERIMENT POINTING SUBSYSTEMS (EPS) REQUIREMENTS FOR SPACELAB MISSIONS

I. INTRODUCTION

The goal of the Experiment Pointing Subsystems (EPS) is to accommodate a broad spectrum of instrument types by providing a number of stability and control functions that greatly exceed the capability of the Shuttle. These functions include target acquisition, target tracking through wide gimbal ranges, stabilization, simultaneous pointing to one or more targets, instrument rastering, and on-orbit calibration. The experiments will vary widely in size, weight, geometry, and instrument types, and many have not been completely defined. This great diversity of requirements reflects the long term plans of the user community and establishes challenging performance requirements for the EPS. The wide ranges of requirements probably will not allow the design of a single standard pointing system, but rather necessitate the eventual development of a family of experiment pointing systems from which the mission planners can choose the most optimum systems to meet a specific objective.

The requirements in this document are separated according to function into stellar, solar, and earth pointing categories. The differences in requirements between these areas may permit more specialized and practical EPS designs. Actual image stability requirements are presented along with the resulting EPS requirements.

II. EXPERIMENT ACCOMMODATION REQUIREMENTS

Table 1 presents a composite of all experiment pointing and control requirements. This summary table shows the range of sizes and weights for the entire spectrum of fine pointing instruments and the most stringent pointing and stability requirements. The correlation between experiment size and performance or the percentage of experiments that could be satisfied by a given level of stability can be compared by consulting Table 1 and the appendix.

TABLE 1. EPS REQUIREMENTS SUMMARY

REQUIREMENTS	UNITS	STELLAR	SOLAR	EARTH
PAYLOAD SIZE:				
DIAMETER	m	0.4 → 3.7	0.2 → 2	0.4 → 2[c]
LENGTH	m	1 → 9.5	2 → 7	0.2 → 3
PAYLOAD MASS:	kg	60 → 5000	30 → 5000	100 → 1400
GIMBAL RANGE:				
LOS	deg	±60	±60[a]	±60
ROLL	deg	±90	±90	±90
GIMBAL SLEW RATE:	deg/min	30	20	90
PERFORMANCE (3σ):				
POINTING: LOS	arc s	±1	±2.5	±36
ROLL	arc s	±120	±60	±360
STABILITY: LOS	arc s	±0.2	±0.1	±1.0
ROLL	arc s	±12	±4[b]	±2
STABILITY DURATION:	s	3600 → 5400	10 → 1000	2700

(a) MAY BE REDUCED IF PAYLOAD BAY ALIGNMENT TO SUN IS PERMISSIBLE FROM THERMAL CONTROL CONSIDERATIONS
(b) THE USE OF A SCENE TRACKER WILL PERMIT ± 30 arc s
(c) SOME ANTENNAS WILL BE 18 m ON A SIDE

The requirements in Table 1 are similar to those published in NASA TM X-64896 except stability levels are an order of magnitude more stringent. This change results from a firm position by the experimenters that Image Motion Compensation (IMC) not be an integral part of many fine pointing instruments because of technological or economic limitations. A change in gimbal range for solar pointing instruments was necessary, because thermal restrictions on Shuttle may prevent orientations of the payload bay directly into the sun. Another potential impact is the change in gimbal slew rate for solar instruments. New raster profiles are the basis for this requirement.

Stellar instruments generally require long exposure times, low tolerance to contamination, and simultaneous pointing to multiple targets. Target search shall be initiated by ephemeris data inputs that drive the instrument to within a few degrees of the target. The EPS gimbal readout must have a resolution of approximately 0.5° for coarse acquisition. Star trackers with a sensitivity to seventh order magnitude guide stars must be available for automatic acquisition and position reference. The alignment and accuracy of the star trackers to the experiments must be adequate to assure acquisition of a target within a 4 arc min field-of-view. Stability of the EPS will be maintained by inertial sensors with star tracker updates.

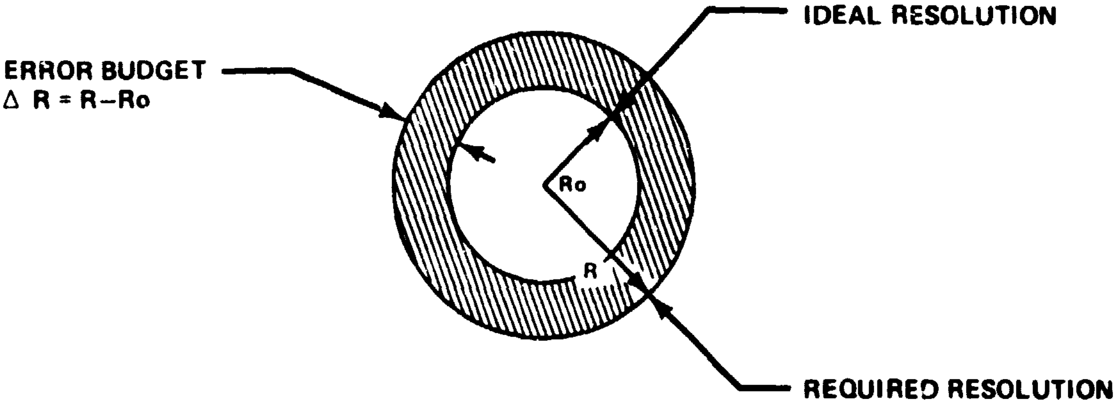
A number of individual solar instruments will be clustered on a single EPS. Some instruments remain sun centered while others search the surface of the solar disk. The sun centered instruments must be controlled separately from the offset pointing instruments. The former must have the option of driving the EPS with an error signal that is generated internal to the instrument. The latter must be stabilized by an EPS mounted fine sun sensor or correlation tracker. The fine sun sensor must have offset capability of at least ±1.0°. On-orbit calibration will be required to align the instruments with the sensors.

Earth pointing instruments will be required to operate in three basic modes as follows: (1) tracking a point on the surface of the earth, (2) following an arbitrary contour, such as a river or coastline, and (3) pointing to the earth's limb. Absolute pointing may be established by reference beacons on the earth's surface, by navigational satellites, by celestial reference or by manual control from a display. The pointing reference is usually payload peculiar; therefore, earth reference sensors are not considered to be the responsibility of the EPS developer. Gimbal range must be sufficient for tracking through a ±60° cone from the payload bay. Instrument stability must permit the resolution of objects 10 m in diameter on the earth's surface from an altitude of 200 km. This stability level is considered to be achievable with a combination of celestial

and inertial sensors with the appropriate software. The sensors necessary for stabilization are not payload dependent and are therefore assumed to be supplied as part of the EPS. More specialized sensors such as landmark trackers will be payload furnished only if standard EPS sensors are not adequate.

III. ERROR BUDGET ALLOCATION

The line-of-sight (LOS) stability error budget for each individual instrument was either provided by the instrument designer or it was established in the following manner: Ideal spot size was calculated according to the Rayleigh criteria. Errors can increase this spot size and degrade resolution as shown in Figure 1. These errors are divided equally between the three contributors as shown in Figure 2. The pointing stability error is then budgeted to each of the three individual pointing axes.



$$\Delta R = (\Sigma \ \Delta_i^2)^{1/2} \quad n \ 1$$

Δ_1 = OPTICS: FABRICATION, INITIAL ALIGNMENT

Δ_2 = MECHANICAL STABILITY OF OPTICAL ELEMENTS

Δ_3 = POINTING STABILITY

Figure 1. Stability error derivation.

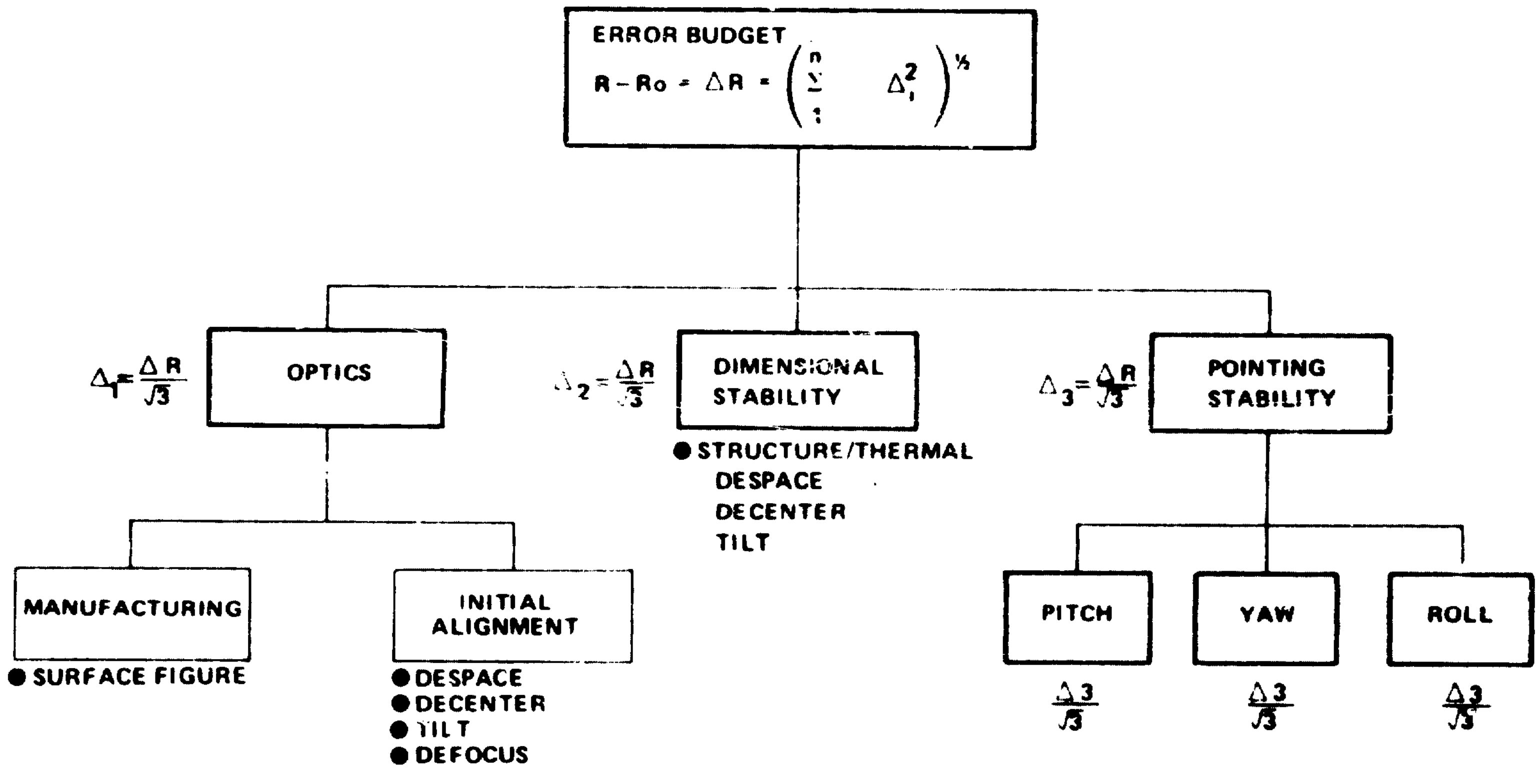


Figure 2. Typical instrument pointing system error budget allocations.

These steps can be expressed in equation form. Enlargement of spot size can be written:

$$\epsilon = \left(\frac{\Delta R}{Ro}\right) Ro$$

$$\epsilon = \frac{1}{F} Ro \quad ,$$

where 1/F is defined as the ratio of acceptable increase in spot size to the ideal size. Enlargement of the spot by 50 percent (F = 2) is considered to be acceptable for some instruments. However, an increase of approximately 10 percent (F = 10) is the goal for diffraction limited instruments. An increase of 30 percent (F = 3.33) is chosen as a representative value to be used if not provided by the instrument designer.

The pointing stability contribution to this error budget must be limited to:

$$\epsilon = \frac{Ro}{F\sqrt{3}}$$

and, the contribution of an individual axis must be no more than,

$$\epsilon = \frac{Ro}{F\sqrt{3}\sqrt{3}} \quad .$$

Therefore, for a typical instrument the stabilization requirement is:

$$\epsilon = \frac{Ro}{3.33\sqrt{3}\sqrt{3}} = \frac{Ro}{10} \quad .$$

This requirement will be imposed directly on the EPS except for those instruments which have internal IMC.

The roll stability error budget was based on the criterion that image smear at the edge of the field would not exceed the smear at center of field due to LOS stability. Therefore, the following relationship exists:

$$\epsilon_{Roll} \leq \frac{2\epsilon}{FOV} \quad ,$$

where FOV = total field of view of the instrument in radians. Roll stability for the instruments will be the same as roll stability required on the instrument mount, since IMC will not normally be used to compensate roll errors.

Whenever technically or economically feasible, IMC is usually incorporated as part of the instrument design. The LOS stability requirements for these instruments are significantly reduced from the values shown by the preceding equations unless specified by the instrument designer. The mount stability level was estimated from acceptable IMC gimbal range as follows:

$$\theta = \left(\frac{2q}{f}\right) \gamma$$

where

θ = mount stability requirement

γ = optically acceptable IMC gimbal range

q = distance from controlled mirror to image plane

f = system focal length.

The IMC also imposes a rate limit on the mount, beyond which the IMC tracking error exceeds instrument stability requirements. This limit is given by:

$$\dot{\theta} = \frac{\omega \epsilon}{2\xi\left(\frac{2q}{f} + 1\right)} \quad ,$$

where

$\dot{\theta}$ = mount stability rate limit

ω = natural frequency of the IMC controller

ζ = controller damping ratio.

The rate limit ($\dot{\theta}$) represents a maximum amplitude and is independent of disturbance frequency or waveshape. The error definitions used in this report are presented in Figure 3.

IV. OPERATIONAL REQUIREMENTS

This section covers the general operational requirements that are needed to maintain a design philosophy consistent with the Shuttle and Spacelab. Only those items that are unique to the EPS are included in this document. The more general Spacelab requirements will also be applicable to the EPS.

A. Operational Flexibility

In view of the diversity of individual instruments it is necessary to maximize operational flexibility through incorporation of modularity and commonality into the design of the EPS hardware. Certain EPS subsystems may be reconfigured from mission to mission, even within one discipline. Typical in this respect would be the exchangeability of the optical bench to substitute a different set of experiments without a complete dissassembly of the EPS. Geographic location of the instrument developer may require that certain EPS flight articles be furnished to the development center for integration with the experiments. A modular system design also provides an expedient and cost-effective means for system repairability and maintainability between missions.

Film removal and possible changeout of instruments by Extravehicular Activity (EVA) or manipulator may be required during a mission. Therefore, the EPS configuration shall not limit on-orbit access to instruments located at the telescope focal plane.

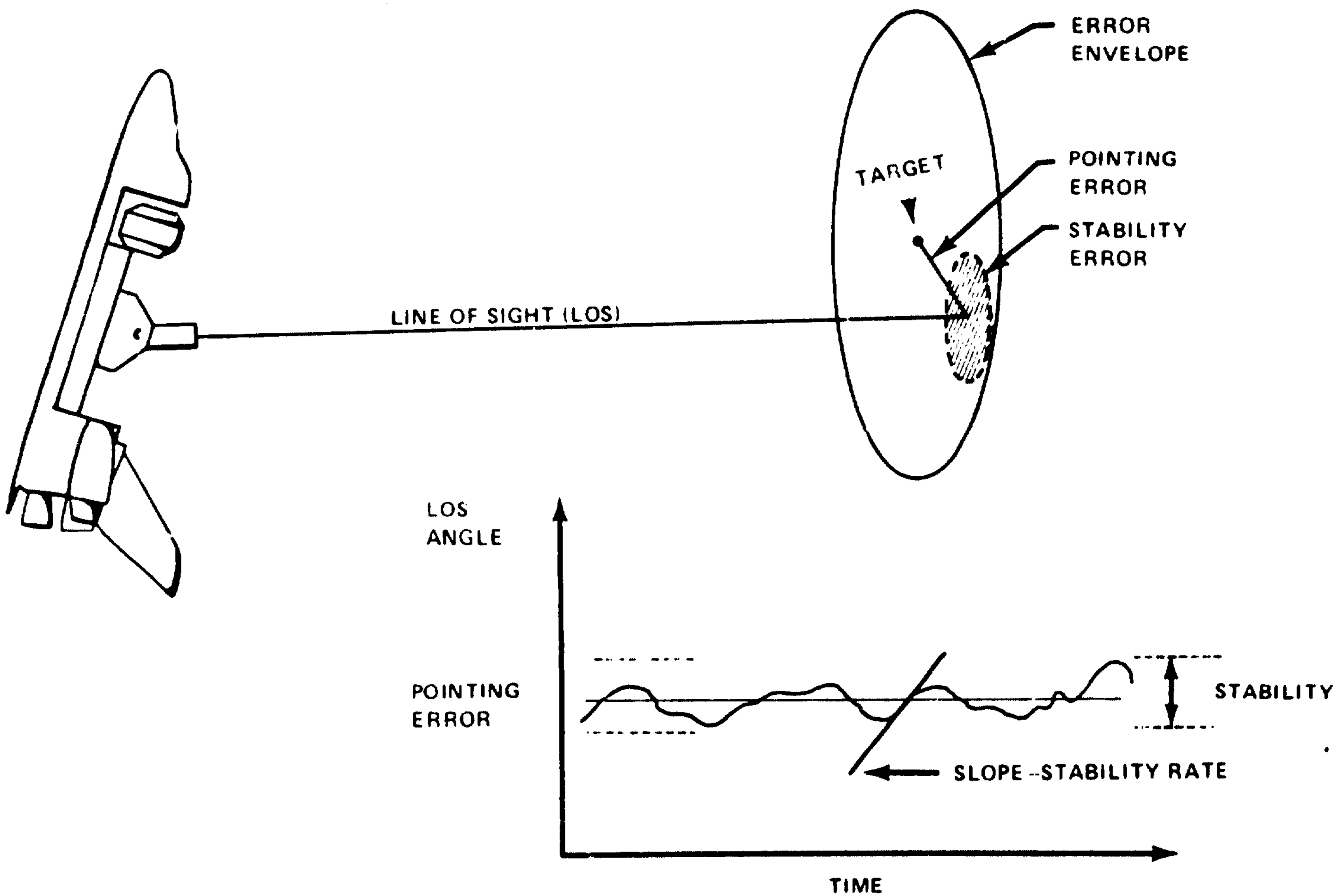


Figure 3. Error definitions.

B. Fluids and Gases

Many of the scientific instruments require cryogenic cooling of their detectors during operation, and some of the detectors may even require cryogenic temperature during their entire lifetime. Practically all optical instruments will require an active, inert gas purge during launch, prior to experiment operation, and during reentry and landing. The EPS design must therefore be responsive to the design implications of cryogenic fluids and gases on the EPS. Fluids and gases under consideration by the instrument designers include all noble gases plus nitrogen, hydrogen, and filtered dry air. Although fluid mass requirements are not identified as yet, typical maximum usage rates are estimated as follows:

LHe	10 kg/day
SCHe	25 kg/day
LN_2	35 kg/day.

C. Environmental

All high voltage circuits, such as star tracker photomultiplier circuits, must be designed to prevent arcing and corona. Packaging designs must be based on circuit operation throughout the critical pressure range. Because of the relatively short duration of the sortie missions it is imperative that component outgassing does not delay experiment operation beyond the time period required for readying the Shuttle and Spacelab systems. Design guidelines are given in MSFC document 50M05189, entitled "High Voltage Design Criteria."

D. Software

The software must be of modular design that will facilitate changes to experiment pointing requirements on a mission-to-mission basis. The software must provide, as a minimum, the following functions in support of the EPS: (1) generate gimbal angle commands in response to ephemeris data inputs, manual control, or sensor error signals, (2) accept data inputs such as Shuttle attitude data and time updates, (3) perform time sequencing and mode switching, and (4) provide redundancy management. Provision will be made for automatic slewing and search patterns. EPS commands shall be coordinated with IMC drive commands for those instruments with IMC.

E. Safety

The mechanical support provisions for the pointing platform(s) and payload equipment in the stowed position must be such that no parts will break free and endanger the crew during Orbiter crash landing loads. The EPS must provide a redundant system for return into the stowed position, or, alternatively, must enable jettison of any equipment deployed outside the Orbiter payload bay dynamic envelope. The interfaces containing the devices for jettisoning payloads or instruments shall be designed such that major damage to jettisoned experiments is avoided in order to allow recovery of high cost items.

F. Test

Proper mechanical operation of the gimbal system shall be verified during prelaunch tests; therefore, it is necessary to make functional tests of the EPS in a 1 g environment. Testing shall not be required at full gimbal range. Provisions shall be made for testing the EPS as a "stand-alone" item without payload.

Ground functional tests will be limited to interface and polarity verification once the payload has been installed in the EPS and the Spacelab/EPS has been installed in the cargo bay. Performance testing of the combined EPS and payload shall not be required.

V. DESIGN GUIDELINES

These informal guidelines are intended to define a typical set of conditions under which the EPS must meet performance requirements. Certain conditions that were found to be a problem for Skylab and those that could be potential problem areas for Spacelab are identified for information only.

A. Disturbances

Crew motion was found to be the most significant external disturbance during the Skylab missions. Since restraining crew motion is an unrealistic design goal, the EPS should be designed to compensate for this activity. A design profile based on Skylab data plus aircraft zero-g flights are presented in Figure 4. A maximum force of 100 N is recommended to represent a typical level of crew activity within the Orbiter or Spacelab.

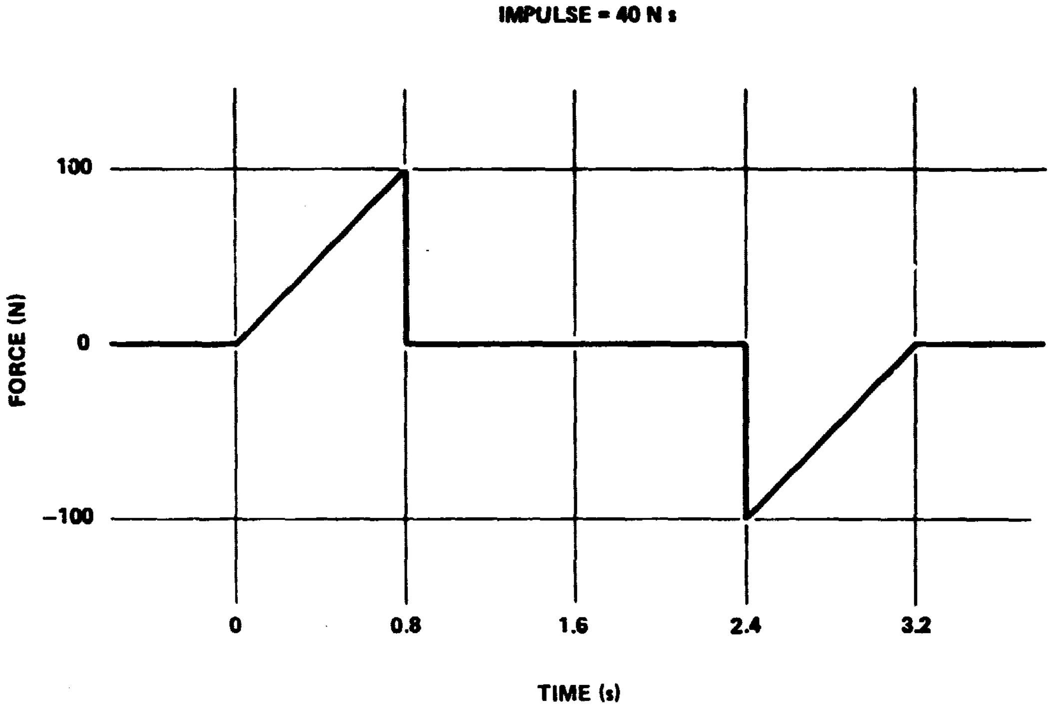


Figure 4. Crew motion design profile.

The vernier control thrusters have a level of 111 N and minimum on-time of 40 ms. The firing frequency is dependent on a number of factors but will typically be approximately one firing every 5 s with minimum on-time. The Shuttle can operate within a deadband of about ±0.1° per axis with a limit cycle rate of approximately ±0.003°/s per axis. Nonminimum impulse firings may be used to reduce firing frequency. In this case, limit cycle rates could be approximately 0.01°/s.

The internal experiment disturbances on Skylab included shutter operation and mirror scan motions. Although these disturbances were quite small, they should not be entirely neglected for Spacelab experiments; additionally, it should be considered that fluids may be stored on the instruments or individual instruments may have an offset drive capability relative to a common experiment base.

B. Gimbal Arrangement

An inner gimbal that permits roll about the instrument LOS offers some important advantages. This arrangement separates the functions of pointing to the target and alignment of slits or polarimeters on individual instruments. Gimbal angle commands can also be input directly into roll without coupling into the other axes. The roll requirements may be much less stringent than for the other axes or may not exist at all for many experiments. Therefore, this arrangement could allow for an add-on roll capability or a much simpler bearing and drive mechanism on the roll axis. The order of the other two gimbals is somewhat arbitrary, but any arrangement that could result in "gimbal lock" or excessive drive rates should be avoided.

C. Thermal Control

To maintain various instruments within their respective temperature limits, active thermal control systems will be needed. Because of the conflicting thermal design requirements of various missions, an active thermal control system will allow the payload integrator to accurately specify the thermal interfaces and requirements that must be met by both the carrier and payload. This approach will allow parallel design efforts to be conducted without the constraint of thermal interdependence.

The EPS must be capable of accommodating an active thermal control system such as a shroud containing cooling fluid that encloses the telescopes or encloses an optical bench to which several telescopes are mounted.

VI. INDIVIDUAL INSTRUMENTS SPECIFICATIONS

The appendix presents a listing of fine pointed instruments which have been proposed by the scientific community in the United States and are endorsed by the NASA Program Offices as representative instruments for Space Shuttle sortie missions.

Six disciplines contain experiments that require pointing and stabilization of instruments and sensors more demanding than provided by the Space Shuttle Orbiter (0.1°): solar physics, astronomy, high energy astrophysics, atmospheric and space physics, earth observation, and earth and ocean physics. LOS stability requirements from the appendix are presented graphically in Figure 5. Bars represent image stability requirements. Shaded areas represent EPS requirements.

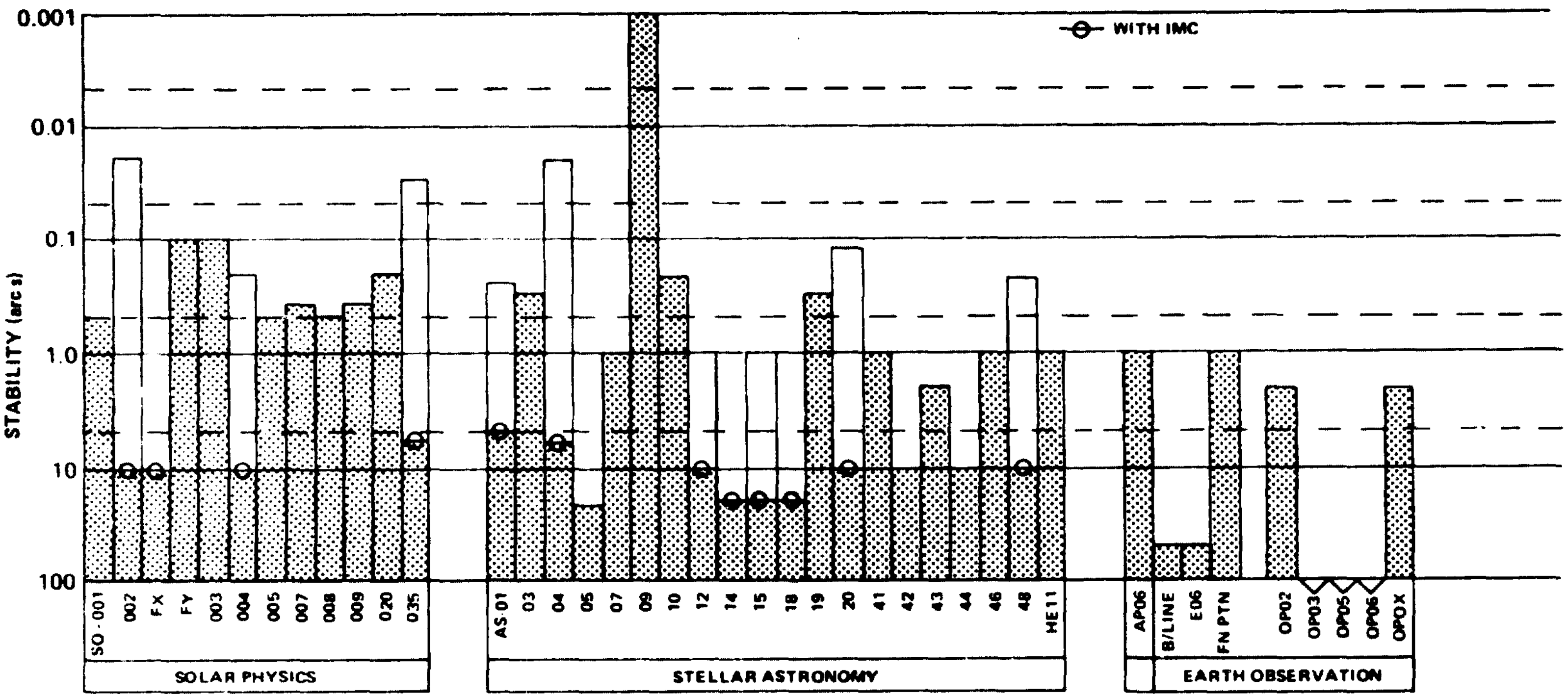


Figure 5. Experiment and EPS stability requirements (P and Y) (3σ).

APPENDIX

INSTRUMENT WITH FINE POINTING REQUIREMENTS

TABLE A-1. INSTRUMENT WITH FINE POINTING REQUIREMENTS, SOLAR

NO.	INSTRUMENT	DIM (m) L x H x W or L x D	DRY WEIGHT (kg) (b)	POWER (Watts) (b)		FIELD OF VIEW arc s		POINTING ACCURACY arc s	ANGULAR RESOL. arc s	ALLOWABLE POINTING STABILITY ERROR (3 σ) arc s (e)				RASTER PROFILE NUMBER
										INSTRUMENT		EPS		
				OPR.	PK.	INSTANT.	TOTAL			P, Y	R	P, Y	R	SPECIFIED IN TABLE A-2
	SOLAR PHYSICS													
	Non-Facility Instruments													
S0001	Coronagraph, Ext. Occulted	4.6 x .6 x .6	204	40	100	11,500	11,500	20	4	0.8	16	(a)	(a)	None
S0003	UV Spectrograph	3 x .5 x .5	250	50	100	0.5x900	2,000	10	0.5	0.1	20	(a)		None
S0004	EUV Spectroheliometer	3.7 x.61 x.66	270	100	120	30	2,000	5	1	0.2	40	10(c)		None
S0005	XUV Spectrometer/Spectroheliograph	2 x .4 x .2	150	15	20	2.5	3,600	5-10	2.5	0.5	60	(a)		1
S0020	Soft X-Ray Telescope/ Spectrograph	3 x .5 x .5	250	50	110	2,000	2,000	10	1	0.2	40	(a)		None
S0007	Soft X-Ray Spectrometer/ Spectroheliograph	4 x 1 x .6	270	60	100	2	2,000	10	2	0.4	80	(a)		1
S0008	Photometer, Grid Collimator Acquisition	2 x .25 x.25	30	5	15	300	7,200	5	5	0.5	30	(a)		4
S0035	Photoheliograph (65cm)	4.0 x 1.0x1.0	900	50	80	180	2,000	10	0.25	0.03	6(d)	7(c)		2
	Solar Facility Instrument													
S0002	Photoheliograph, 100cm	7.1 x 1.5 x 2	1750*	500	800	180	2,000	10	0.15	0.02	4(d)	10(c)	(a)	2
FX	XUV Facility	7 x 1 x 1.5	1050*	300	450	0.5	3,600	2.5	0.5	0.1	20	10(c)		Internal
FY	Soft X-Ray Facility	7 x 1 x 1.5	2250*	300	450	0.5	3,600	2.5	0.5	0.1	20	(a)		3
S0009	Collimator, Modulation	3.1 x 1 x 1	350*	100	200	4	2,000	4	4	0.4	80	(a)		4

(a) Same as Instrument (no IMC Capability)
(b) Weight and Electrical Power of Thermo Control Canister Not Included)
(c) Assumes 30 Hz Band Width on IMC.
(d) For Sun Centroid Guiding; Use of Scene Tracker Will Relax Requirement to ~30 arc s
(e) Experiment Operation: 10 s to 15 min (Typically) per Observation
* Includes Prorated Weight of Spar + Thermal Control Canister. Facilities May be Combined on Single Mount (Not Exceeding 5000Kg)

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TABLE A-2. SOLAR PHYSICS INSTRUMENT RASTERING REQUIREMENTS

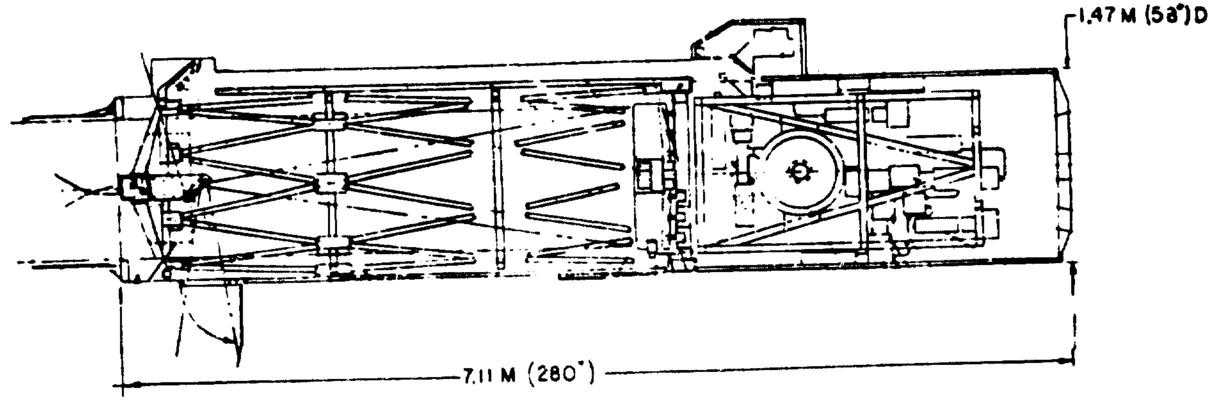
Raster Parameters	Unit	Profile 1					Profile 2	Profile 3	Profile 4
		a	b	c	d	e			
Raster Size	arc min	60 × 60	15 × 15	5 × 5	1.5 × 1.5	0.5 × 1	1 × 1	1.5 × 1.5	Line Scan: Oscillatory 2 deg at 20 arc min/s
Approximate Time/Raster	s	900	124	56	20	900	20	20	
Separation of Scan Lines	arc s	30	20	10	5	1	1.0	2.5	Dither Scan: Circular with 10 s dia. 1 s accuracy Repetitively with period of 1 s.
Line Scan Rate	arc s/s	480	320	160	80	2	180	160	
Required Scan Accuracy (90 percent of Raster Duration and 90 percent of Each Scan Line)	arc s	10	6.7	3.3	1.7	0.7	0.33	0.83	0.4

Raster data provided by Dr. W. Neupert, GSFC.

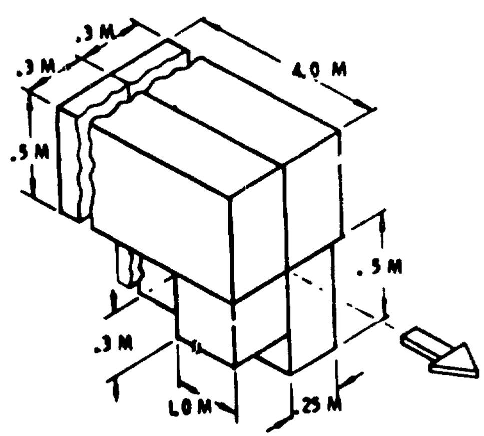
SUPPLEMENT TO ' ABLE A-1.

S0002 100Cm PHOTOHELIC ^APH

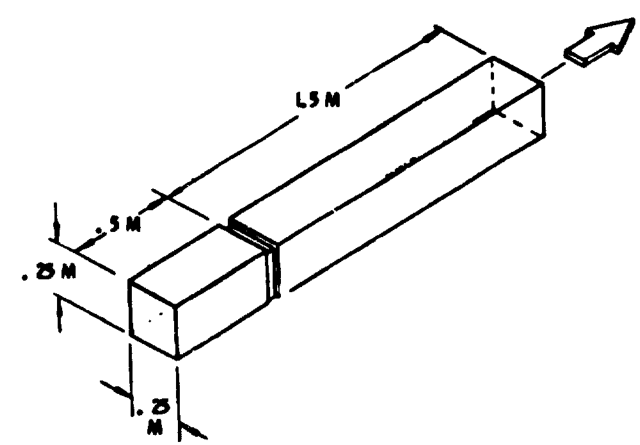
S0035 65 Cm PHOTOHELIOGRAPH IS SIMILIAR CONFIGURATION



SO 007 SPECTROMETER, SOFT X-RAY/SPECTROHELIOGRAPH

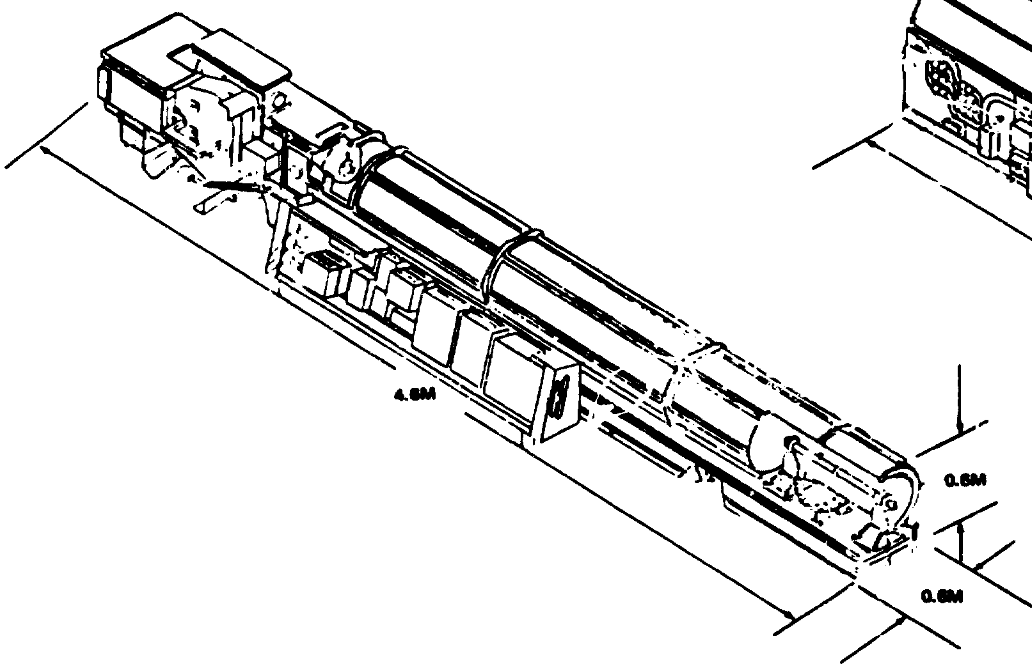


SO 008 PHOTOMETER, GRID COLLIMATOR ACQUISITION

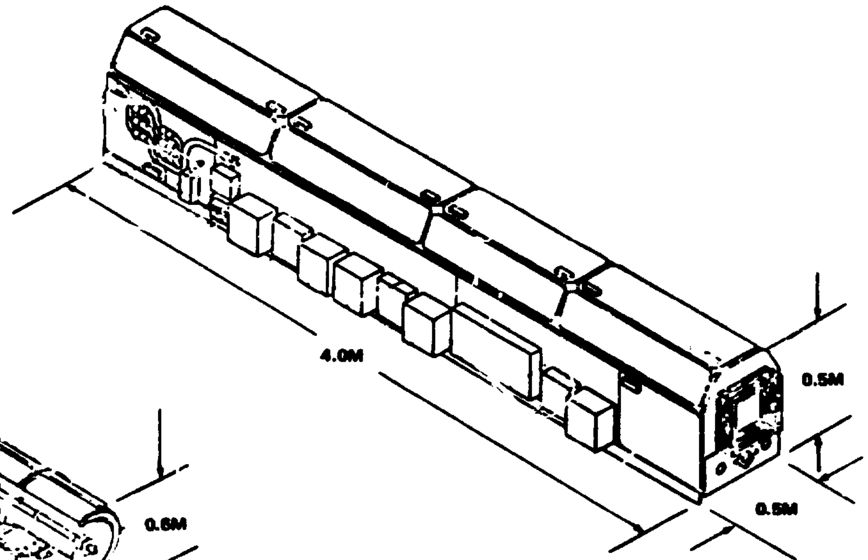


SUPPLEMENT TO TABLE A-1.

S0001 CORONAGRAPH EXT. OCCULTED



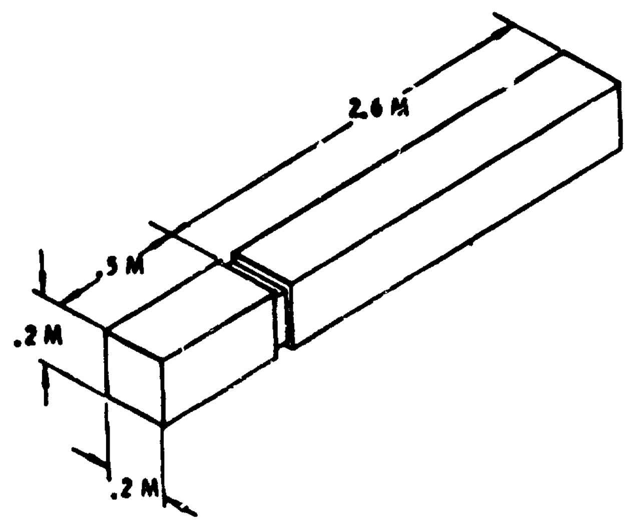
S0003 SPECTROGRAPH U. V.



S0004 SPECTROHELIOMETER EXTERNAL U. V. AND S0005 SPECTROMETER/ SPECTROHELIOGRAPH ARE SIMILAR CONFIGURATION TO S0001 AND S0003

SUPPLEMENT TO TABLE A-1.

SO 003 COLLIMATOR, MODULATION



SO 020 SOFT X-RAY SPECTROGRAPH TELESCOPE

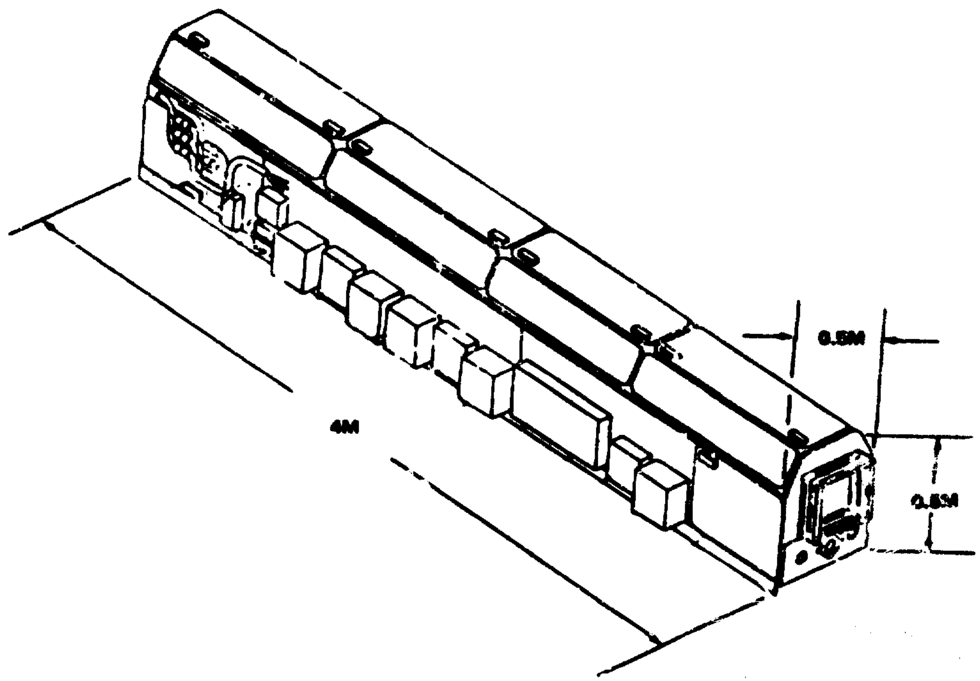


TABLE A-3. INSTRUMENT FINE POINTING REQUIREMENTS, ASTRONOMY

NO.	INSTRUMENT	DIM (m) L × H × W or L × D	DRY WEIGHT (kg)	POWER (Watts)		FIELD OF VIEW arc s		POINTING ACCURACY arc s	ANGULAR RESOL. arc s	ALLOWABLE POINTING STABILITY ERROR (3 σ) arc s (e)				RASTER PROFILE NUMBER
										INSTRUMENT		EPS		SPECIFIED IN
				OPR	PK	INSTANT	TOTAL			P, Y	R	P, Y	R	TABLE N/A
	ASTRONOMY													
AS01S	Cryo-Cooled IR	5.0[(a)] x 2.4	3000[(b)]	250	300		900	30	2.5	0.27	25	5	25	None
	[illegible]Om IR (Nominal)		(2060)											
	[illegible]otometer, IR Filter		(25)											
	[illegible]ay, Detector		(25)											
	Spectrometer, Interferom-[illegible]ter		(25)											
	Polarimeter		(25)											
	Spectrometer, Grating		(25)											
	Spectrophotometer		(25)											
AS03S	Deep Sky UV Survey	2x2.2x1.2(ea)	3450[(c)]				18000	5	0.5	0.3 (1)	8 (25)	0.3 (1)	8 (25)[(d)]	None
	Folded [illegible] Reflective													
	Schmi[illegible] Required)		(1130)	10	30									
	Conve[illegible]/Intensifier		(27.3)	210	230									
	Film Magazine		(10)	N/A	N/A									
	Wide Field Aspect Monitor [illegible] Tracker		(22.7)	30	40									
AS04S	[illegible]m UV Telescope	4.0[(a)] x [illegible].8	1266				1800	3	0.17	0.02	12	6	12	None
	1m Dif. Lim. UV Telescope		(1141)	80	140									
	Spectrograph, Imaging		(30)	50										
	Spectrograph, Echelle		(50)	50										
	Spectrograph, Lyman		([illegible])	50										
	Cameras, Fie[illegible]		(15)	10										

(a) Plus 2m Sunshield
(b) Includes Cryogen Coolant
(c) For Three Telescopes (Two Might be Acceptable)
(d) Degraded Scientifically to Maximum Acceptable Limits
(e) Experiment Operation: 60 to 90 min (typically) per Observation

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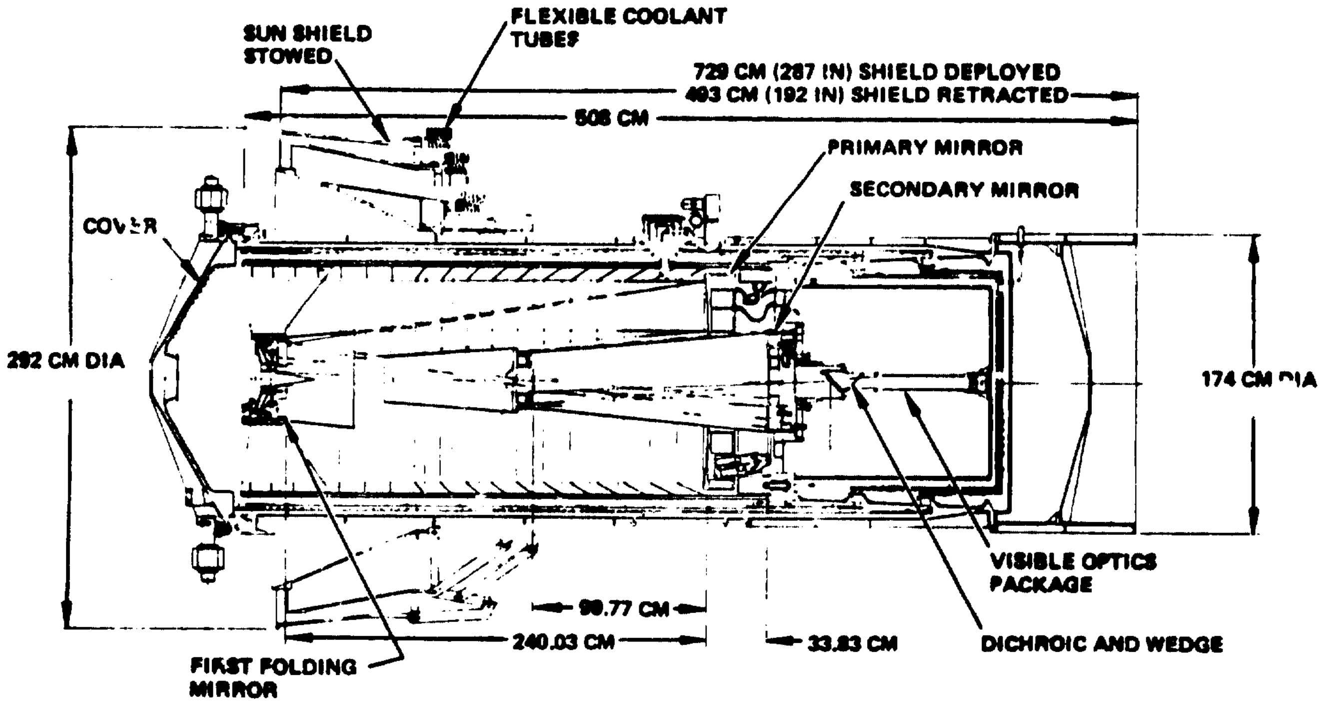
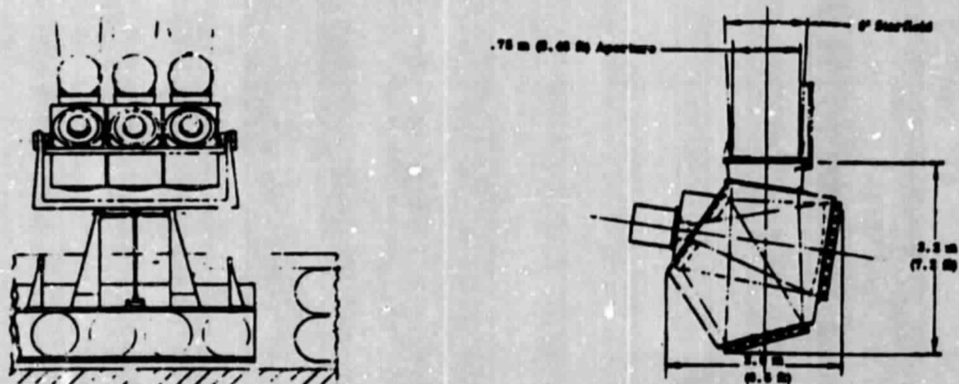
SUPPLEMENT TO TABLE A-3.



AS01S CRYO-COOLED IR TELESCOPE

SUPPLEMENT TO TABLE A-3.



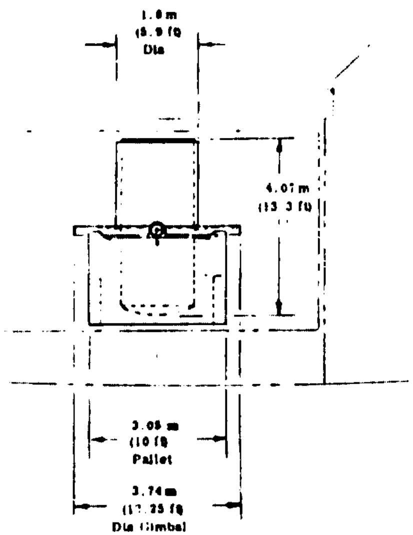
AS03S DEEP SKY U. V. SURVEY

TABLE A-3. (Continued)

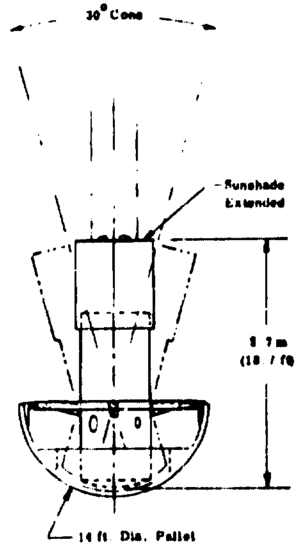
NO.	INSTRUMENT	DIM (m) L x H x W or L x D	DRY WEIGHT (kg)	POWER (Watts) OPR.	POWER (Watts) PK.	FIELD OF VIEW arc s INSTANT.	FIELD OF VIEW arc s TOTAL	POINTING ACCURACY arc s	ANGULAR RESOL. arc s	ALLOWABLE POINTING STABILITY ERROR (3 σ) arc s (e) INSTRUMENT P, Y	INSTRUMENT R	EPS P, Y	EPS R	RASTER PROFILE NUMBER SPECIFIED IN TABLE N/A
AS07S	Cometary Simulation	1.0 x 2.0	454			14,400	14,400	1800	10	1	31	1	31	Tracking of Moving Target at Max Rate of 1^{o}- 2^{o}per 15 min
	Mounting Spar & Canister		(354)											
	XUV Telescope Filter Photometer		(9.1)	7	14									
	XUV Telescope Grating Spectrometer		(18.2)	7	14									
	UV Spectrometer		(6.8)	7	14									
	Visible Spectrometer		(6.8)	7	14									
	IR Interferometer Spectrometer		(13.6)	20	40									
	Far IR Interferometer/ Spectrometer		(13.3)	20	40									
	UV Telescope Camera (Carruthers Type)		(15.9)	7	14									
	TV Camera/Still Camera		(4.1)	20	40									
AS09S	30m IR Interferometer (a)	15.2 x 0.6 x 0.3	1036	TBD	TBD			1	0.004	0.001	TBD	(a)	(a)	None
	Extendable Optical Bench		700											
	0.5m IR Telescope		(225)	10	20									
	Interferometer Star Tracker		(40)	30	45									
	IR Heterodyne Detector		(20)	20										
	Laser Ref. Carrier		(31)	300	TBD									
	Laser Ranging & Signal Receiver		(20)	45	TBD									

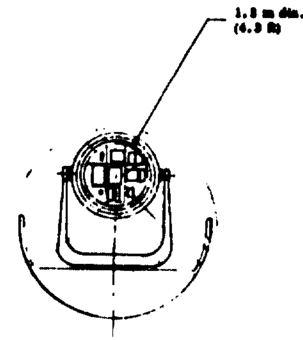
(a) Two Telescopes Mounted on Booms 30m Apart; Presently Beyond State-Of-The-Art for Stabilization by Mechanical Systems
(e) Experiment Operation: 60 to 90 min (Typically) per observation

SUPPLEMENT TO TABLE A-3.

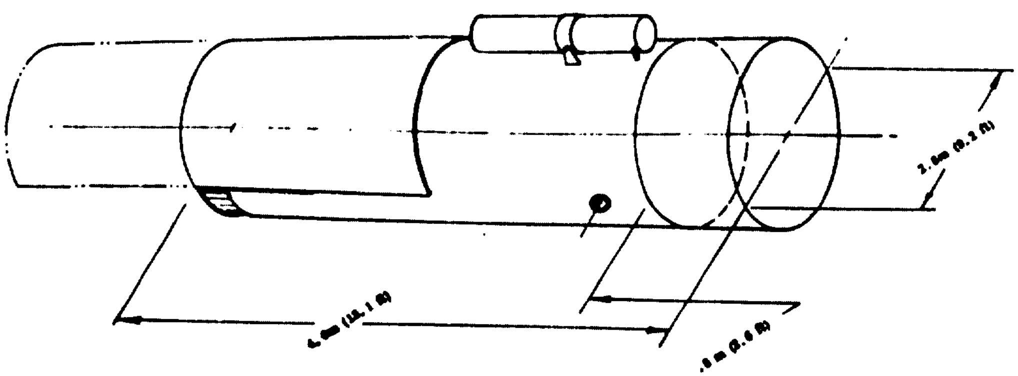


AS04S 1 m U. V. TELESCOPE





AS07S COMETARY
SIMULATION



AS020S 2.5 m CRYO-COOLED IR TE'.ESCOPE

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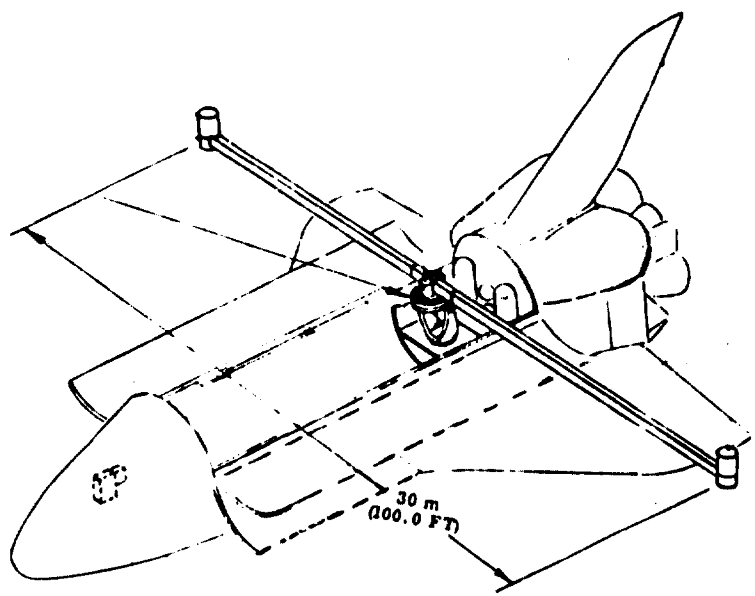
SUPPLEMENT TO TABLE A-3.



AS09S 30 m IR INTERFEROMETER

TABLE A-3. (Continued)

NO.	INSTRUMENT	DIM (m) L x H x W or L x D	DRY WEIGHT (kg)	POWER (Watts) OPR.	POWER (Watts) PK.	FIELD OF VIEW arc s INSTANT.	FIELD OF VIEW arc s TOTAL	POINTING ACCURACY arc s	ANGULAR RESOL. arc s	ALLOWABLE POINTING STABILITY ERROR (3 σ) arc s (e) INSTRUMENT P, Y	INSTRUMENT R	EPS P, Y	EPS R	RASTER PROFILE NUMBER SPECIFIED IN TABLE N/A
AS20S	2.5m Cryo-Cooled IR Telescope	5.5[a] x 2.8	3899	250	400		1,800	10	1	0.11	25	10	25	None
	IR Telescope 2.5m Aperture		(3720)											
	Broadband IR Filter		(25)											
	IR Photoconductor		(25)											
	Fourier Interferometer		(25)											
	Polarimeter		(25)											
	Grating Spectrometer		(25)											
	Moderate Dispersion Photometer		(25)											
	Instrument Selector Mech.		(25)											
	<u>ASTRONOMY PAYLOAD WITH LIMITED DEFINITION</u>													
AS05S	Widefield Galactic Camera	1.2x0.4x0.4	60	28	80		36,000	7,200	60	30	70	30	70	None
AS08S	Multipurpose 0.5m Telescope	1.5 x 0.75	382	100	150		3,600	1,800	10	2	200	2	200	
AS10S	Advanced XUV Telescope	3.0 x 0.5	344	400	450		36,000	1	1	0.2	40	0.2	40	
AS12S	Meteoroid Simulation	2.0 x 1.0	454	1350	1880		1,800	30	5	1	200	10	200	Tracking of Moving Target 1°- 2°/Min
AS14S	1m Uncooled IR Telescope	3.0[a] x 1.5	1235	500	1000		3,600	10	3	1	114	20	114	None
AS15S	3m Ambient IR Telescope	9.5[a] x 3.7	4995	500	570		1,450	5	5	1	285	20	285	
AS18S	1.5 km IR Interferometer[b]	2.5 x 1.2	1600	1500	1775		1,800	1 System(0.002)	3	1	230	20	230	
AS19S	Selected Area Deep Sky Survey Telescope	2.5 x 1.2	890	400	500		11,000	5	1	0.3	11	0.3	11	

(a) Plus 1-2m Sunshield
(b) One Telescope on Spacelab Pointing System; the Other Free Flying at 1.5 Km Distance
(e) Experiment Operation: 60 to 90 Min (Typically) per observation

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TABLE A-3. (Concluded)

NO.	INSTRUMENT	DIM (m) L x H x W or L x D	DRY WEIGHT (kg)	POWER (Watts)		FIELD OF VIEW arc s		POINTING ACCURACY arc s	ANGULAR RESOL. arc s	ALLOWABLE POINTING STABILITY ERROR (3 σ) arc s (e)				RASTER PROFILE NUMBER
										INSTRUMENT		EPS		SPECIFIED IN TABLE N/A
				OPR.	PK.	INSTANT.	TOTAL			P, Y	R	P, Y	R	
AS41S	Schwartzschild Camera	1.9 x 0.38	139.5	80	100		11,000	360	5	1	37	1	37	None
AS42S	Far UV Electronographic Schmidt Camera/Spectrograph	1.0 x 0.4	110	30	44		36,000	3600	30	10	114	10	114	
AS43A	UCB Black Brant (Typical) GI Telescope	2.8 x 0.45	351	140	280		36,000	60	10	2	23	2	23	
AS44S	XUV Concentrator/Detector	1.7 x 0.45	84	150	200		21,600	100	30	10	570	10	570	
AS46S	Wisconsin UV Photometry	1.2 x 0.4	68	30	50		7,200	60	5	1	290	1	290	
AS48S	Aries/Shuttle UV Telescope	3.8 x 1.1	400	250	300		3,600	1	1	0.2	23	10	23	
	European Experiments *													
	Large IR Ambient Temperature Telescope (3m)	7.65 x 3.45	4540				1,800	5	5	2	360	40	360	None
	1m UV Telescope	4 x 1.25	1080				618	1	0.5	0.1	20	TBD	TBD	
	X-Ray Spectropolarimeter	1 x 2 3.3 x 0.8	850				60	60	60	60	TBD	TBD	TBD	

* A. Lemarchand, 2-3-75

(e) Experiment Operation: 60 to 90 min (Typically) per observation

TABLE A-4. INSTRUMENTS WITH FINE POINTING REQUIREMENTS, ASTRONOMY

NO.	INSTRUMENT	DIM (m) L x H x W or L x D	DRY WEIGHT (kg)	POWER (Watts) OPR.	POWER (Watts) PK.	FIELD OF VIEW arc s INSTANT.	FIELD OF VIEW arc s TOTAL	POINTING ACCURACY arc s	ANGULAR RESOL. arc s	ALLOWABLE POINTING STABILITY ERROR (3 σ) arc s INSTRUMENT P, Y	INSTRUMENT R	EPS P, Y	EPS R	RASTER PROFILE NUMBER SPECIFIED IN TABLE N/A
	HIGH ENERGY ASTROPHYSICS													
HE11S	X-Ray Angular Structure	1.5 x 3.97	4857	37										
	Counter, Proportional Array	4 Systems	(2000)			3,600	3,600	360	360	(a)	(a)			Scanning Rate 3.6 min/s
	Counter, Scintillation Array	7 Systems	(2800)			18,000	18,000	360	360	(a)	(a)			
	Optics, Telescope Aspect Sensor		(47.8)			18,000	18,000	10	10	1	N/A	1	N/A	
	Tracker, Field Monitor		(9.1)			-	-	-	-					

(a) Telescope Aspect Sensor Provides Post Flight Correlation of Position and Stability Information

SUPPLEMENT TO TABLE A-4.

X-RAY ANGULAR STRUCTURE HE11S

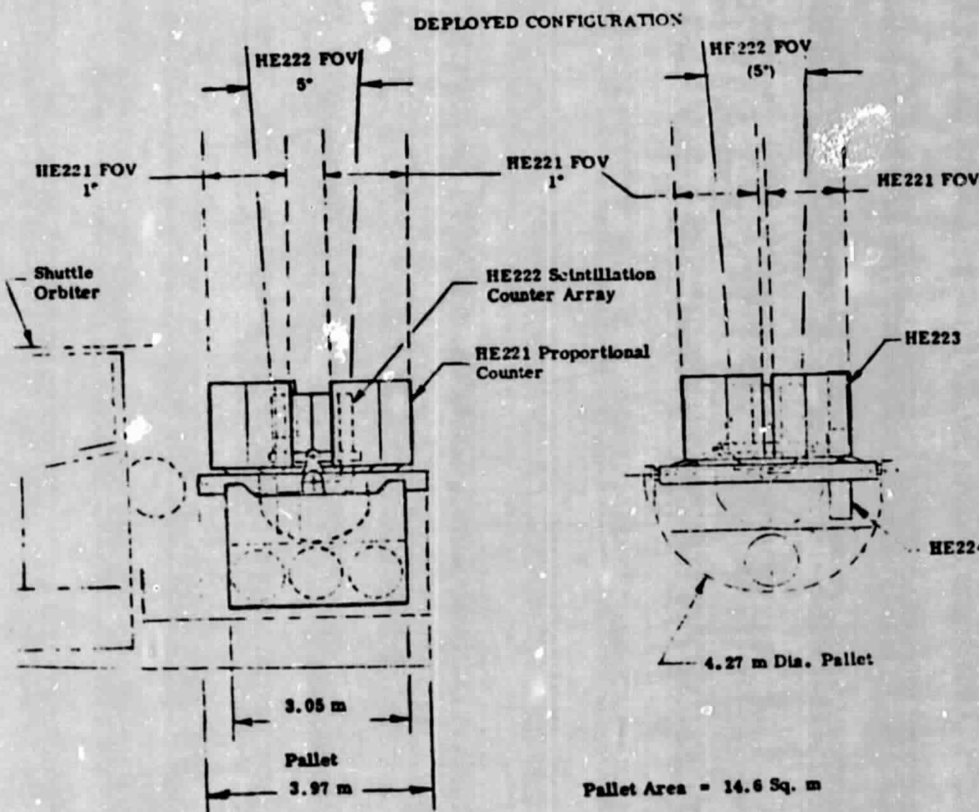

TABLE A-5. INSTRUMENT WITH FINE POINTING REQUIREMENTS, ATMOSPHERIC

NO.	INSTRUMENT	DIM (m) L x H x W or L x D	DRY WEIGHT (kg)	POWER (Watts)		FIELD OF VIEW arc s		POINTING ACCURACY arc s	ANGULAR RESOL. arc s	ALLOWABLE POINTING STABILITY ERROR (3 σ) arc s (e)				RASTER PROFILE NUMBER
										INSTRUMENT		EPS		
				OPR.	PK.	INSTANT.	TOTAL			P, Y	R	P, Y	R	SPECIFIED IN TABLE N/A
	ATMOSPHERIC & SPACE PHYSICS													
AP06S AP100	Atmospheric, Magnetospheric & Plasmas in Space (AMPS) (Remote Sensing Platform)	1.5 x 1.93	923	200	-	1800	1800	180	2	1	50	1	50	

(e) 30 min. Duration (Typically)

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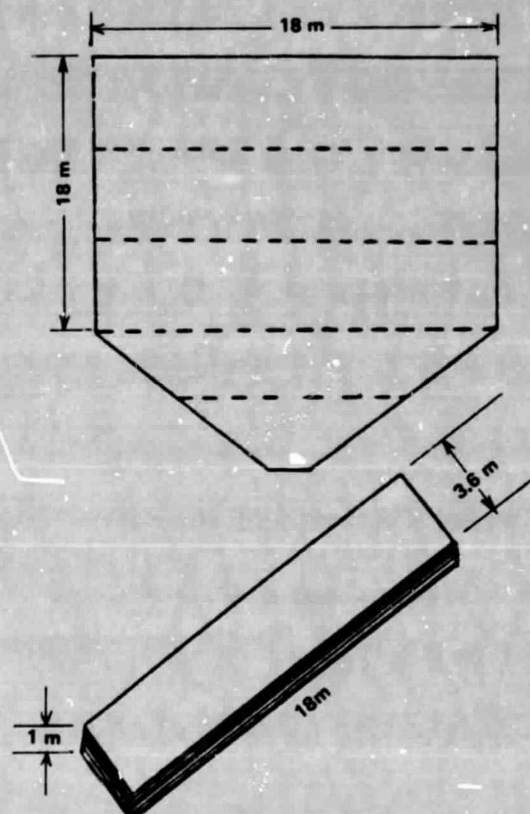
TABLE A-6. INSTRUMENTS WITH FINE POINTING REQUIREMENTS, EARTH OBSERVATIONS

NO.	INSTRUMENT	DIM (m) L x H x W or L x D	DRY WEIGHT (kg)	POWER (Watts)		FIELD OF VIEW arc s		POINTING ACCURACY arc s	ANGULAR RESOL. arc s	ALLOWABLE POINTING STABILITY ERROR (3 σ) arc s				RASTER PROFILE NUMBER
										INSTRUMENT		EPS		SPECIFIED IN TABLE N/A
				OPR.	PK	INSTANT.	TOTAL			P, Y	R	P, Y	R	
	EARTH OBSERVATIONS													
	Baseline System							300 to 1800		50 to 100	100 to 200	50 to 100	100 to 200	
	Typically:													
E005S	Shuttle Imaging Microwave System (SIMS)	18 x 3.6 x 1	1427	1100	1300	100	30(Deg)	360	100	50	190	50	190	
	Fine Pointing System													
	Typically:													
	Scanning Spectroradiometer	2.13 x 0.9	202	250		3600	40(Deg)	36	10	1	2	1	2	

SUPPLEMENT TO TABLE A-6.



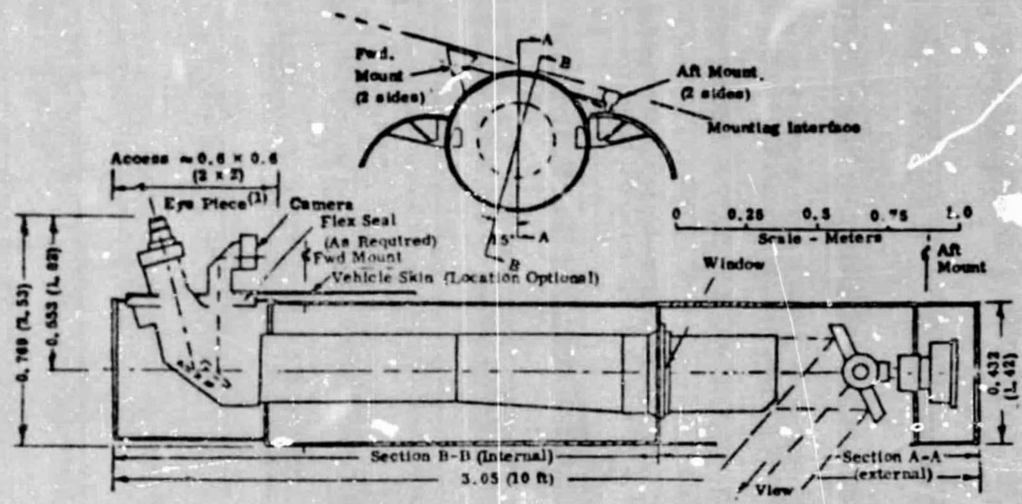
E005S SHUTTLE IMAGING
MICROWAVE SYSTEM
(SIMS)

TABLE A-7. INSTRUMENTS WITH FINE POINTING REQUIREMENTS, EARTH OBSERVATIONS

NO.	INSTRUMENT	DIM (m) L x H x W or L x D	DRY WEIGHT (kg)	POWER (Watts) OPR.	POWER (Watts) PK.	FIELD OF VIEW arc s INSTANT.	FIELD OF VIEW arc s TOTAL	POINTING ACCURACY arc s	ANGULAR RESOL. arc s	ALLOWABLE POINTING STABILITY ERROR (3 σ) arc s INSTRUMENT P, Y	INSTRUMENT R	EPS P, Y	EPS R	RASTER PROFILE NUMBER SPECIFIED IN TABLE N/A
	EARTH AND OCEAN PHYSICS													
	Baseline System													
	Typically:													
OP02S	Multifrequency Radar Land Imagery	0.2 x 3 x 10	403	190	-	4 x 6 (Deg.)	77 X 73 (Deg.)	360	10	2	2	2	2	
	o Antenna													
	o Gimbal & Optical Assy.													
OP03S	Multifrequency Dual Polarized Microwave Radiometry	3.0 x 0.77 x 0.4	109.1	133	-			360	2200	550		550		
OP05S	Multispectral Scanning Imagery	0.2 x 3 x10	403	190	-			360	5000	1250		1250		
OP06S	Combined Laser Experiment	1.1 x 0.4	141.7	283	-	2	100(Deg.)	360	12	180	180	180	180	
OP0XS	**Fine Pointing System**	0.7 x 1 x10	400	300		3600	40(Deg.)	36	10	2.5	2	2.5	2	

SUPPLEMENT TO TABLE A-7.

MICROWAVE SCATTEROMETER OP0[illegible]S



Observation Camera/Telescope

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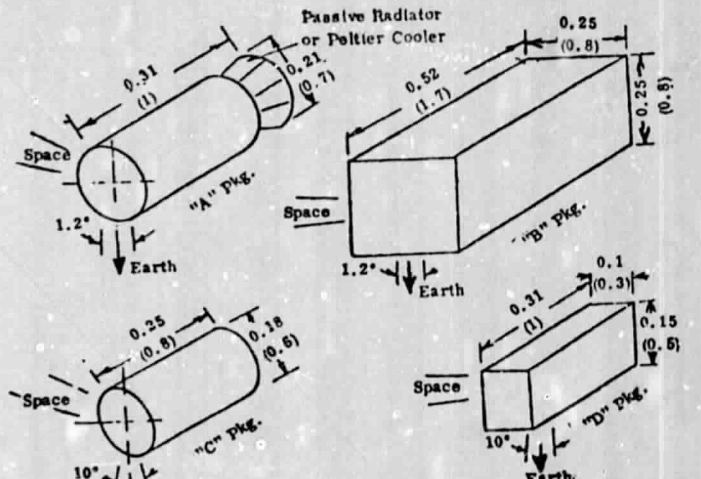
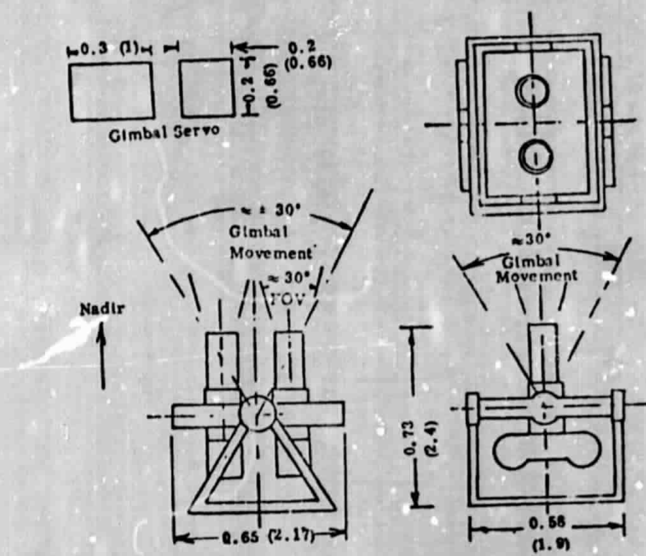
SUPPLEMENT TO TABLE A-7.

MULTIFREQUENCY RADAR LAND IMAGERY OP02S



IR TEMPERATURE
PROFILE RADIOMETER
(OP085 THRU OP089)



WIDE ANGLE CAMERA
(OP091, OP094)

APPROVAL

EXPERIMENT POINTING SUBSYSTEMS (EPS) REQUIREMENTS FOR SPACELAB MISSIONS

By M. E. Nein and P. D. Nicaise

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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